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Modification and Performance Evaluation of Locust Bean Dehulling Machine

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Abstract: The traditional method of processing locust bean including some other bean varieties is time consuming with lots of energy consumption and labour while mechanical method therefore reduces the human drudgery and also increases output. This research was aimed at modifying an existing locust bean dehuller while carrying out the performance evaluation of the machine using four bean varieties (locust bean, soybean, kidney bean and navy bean) for better efficiency.Some of the components modified in the existing machines include: sieves (to have rectangular and circular form), stainless steel (for dehulling and washing chamber), angle iron (for the machine frame in case of rigidity and stability). The factors considered in the modification of the machine include: cost of the materials, construction technique, availability of materials, durability of materials, cost of maintenance and effect of the materials used on the food ingredients. The performance evaluation of the machine was determined based on dehulling efficiency, cleaning efficiency and percentage loss which are calculated at different boiling/soaking time. The results of the performance evaluation show that the dehulling efficiencies of the circular-sieved machine are 82.78%, 81.54%, 77.23%, 78.02% at dehullingtime of 67.11 secs, 71.11 secs, 65.22 secs, 68.33 secs and that of the rectangular-sieved machine are 88.21%, 71.99%, 69.44%, 70.37% at dehulling time of 71.00 secs, 61.00 secs, 62.89 secs, 69.11 secs obtained for locust beans, soybeans, kidney beans and navy beans respectively. The cleaning efficiencies of the circular-sieved machine are 71.89%, 55.26%, 58.73%, 58.45% at dehulling time of 67.11 secs, 71.11 secs, 65.22 secs, 68.33 secs and that of the rectangular-sieved machine are 61.61%, 60.56%, 62.71%, 60.60% atdehulling time of 71.00 secs, 61.00 secs, 62.89 secs, 69.11 secs obtained for locust beans, soybeans, kidney beans and navy beans respectively. It can be observed generally that the dehulling and cleaning efficiencies have direct correlation with the dehulling time and boiling/soaking time.
Keywords: Bean, Dehuller, Dehulling Efficiency, Modification, Performance Evaluation.

I. Introduction

Locust bean *(Parkiabiglobosa)* is one of the leguminous crops generally grown in the tropics and villages in the grassland areas of West Africa mostly in the middle belt of South West Nigeria [1]. The dehulling and cooking of locust bean seeds are fermented to produce a strong smelling food condiments in the entirearea of West Africa. Locust beanis usually called 'iru' in Western Nigeria, 'dawadawa' in Northern Nigeria, 'soumbala' in Burkina Faso, Mali, Coted' ivore and Guinea. The locust bean seed already dehulled and fermented in paste form comprises 32% fat and oil, 40% protein and 25% carbohydrate [1], [2].

Locust bean, produced and fermented into food condiments is still mainly handled by traditional method in most regions of Nigeria and regularly carried out by basictools. According to [3], traditionalproduction stepsof locust beans include the shelling of the mature hulls, sorting into equal range sizes, steaming and boiling in clay pots, dehulling by pounding with pestle and mortar, washing in calabash and consequently fermenting the beans into many condiments by covering them with cloth or banana leaves [1]. According to [4], some consumers further mill the fermented bean into a thick paste while spices such as salts are added before molding into circular palette and sun-dried [1].

Locust bean is characterized by its elongated pods fruits which are 5-11 inches long and found in clusters. It flowers from December to March and brings out fruits from February to July. The immature fruits are green and brown when it is mature. The mature seeds are made up of husk which is embedded in dark brown pod. A lot of research work has been done on the production of African locust bean seeds and related aspects which include storage, preservation, processing, time taken to be cooked, packaging and other areas [5], [6].

The traditional method of processing locust bean is however rather tedious, slow and subjects the bean to excessive water treatment, leading to colour degradation and uncontrolled micro-organism activities. The human drudgery associated with the processing of the product as mentioned by [4], is actually restraining the production and consumption of this local food condiment due to high fuel wood consumption, use of basic equipment, and low production output. Consequently, the consumption of the product has declined hereby promoting importation of imported soup flavours. Thus, there is need to increase the production and supply rate

of this food condiment by developing appropriate and efficient processing technology that can improve the product quality and increase its production rate. The dehulling process can be best achieved by mechanical method rather than making use of feet or pestle and mortar to dehull the taste from the hulls. The traditional method is time consuming cum energy consuming and laborious while mechanical method reduces human drudgery and increases output. Hence, this work was aimed at modifying an existing locust bean dehulling machine and also carry out the performance of the machine using other bean varieties for effective performance. This improved locust bean dehuller will help to reduce the production cost as well as reduces man power which is time consuming particularly in large scale operation.

II. Materials and Methods

(a) Material Selection

The sieves of the existing locust bean dehullerswere modified to be rectangular-sieved and circular sieved for the purpose of this research. The factors considered in the modification of the locust bean dehulling machines include: cost of the materials, construction technique, availability of materials, durability of materials, cost of maintenance and effect of the materials used on the food ingredients. Some of the components modified in the existing machines include: sieves (to have rectangular and circular form), stainless steel (for dehulling and washing chamber), angle iron (for the machine frame in case of rigidity and stability). Other materials used for the research work includes existing locust bean dehullers, petrol engine, weighing machine (scale) locust bean, soybean, navy bean (white bean) and kidney bean (red bean).

(b) Machine Operation and Performance

To achieve effective performance, the existing locust bean dehuller was used to dehull four varieties of beans such as locust bean, soybean, navy bean and kidney bean. These beans are being first dehulled in the dehulling chamber varies on different varieties of the bean. The dehulling shaft is powered by a petrol engine which is connected to the pulley device to further reduce the dehulling and washing speed. As the dehulling shaft rotates, it provides drive to the dehulling stirrer mechanism inside the dehulling unit and the washing unit respectively. As the beans are fed into the dehulling cylinder through the feeding chute (hopper), they are dehulled by abrasive action and then conveyed to the washing unit under the dehulling unit. The stirrer in the inner concentrate cylinder of the washing unit gently stirs the dehulling beans solution to dislodge the coats from the seeds. Due to the variation in the density of the coat and the seed from the density of water, the coat floats on the water which is collected by lowering the outer concentrate of the washing unit with hand operated handle.

(c) Preparation of Samples

The locust beans, soybeans, kidney beans and navy beans were obtained from Oja-Oba Market, Mapo in Ibadan city of Nigeria. 20.16 kg of locust beans seeds were weighed using a digital weighing balance (CAMRY ACS-30-ZE41, CAMRY) and each was sorted out for materials other than the beans after which it was divided into three (3) pieces each of 3 kg before parboiling/cooking. The locust beanswere cooked at different boiling times of 7, 8 and 9 hours. The same kg was weighed for soybeans, kidney beans and navy beans with the digital weighing balance and each was sorted also into 3 pieces having 3 kg each. All other beans undergone soaking process before being dehulled by the dehulling machine. The boiled beans were then dehulled and washed using the existing fabricated rectangular-sieved and circular sieved locust bean dehullers at a desired operating speed. After dehulling, the shaft was removed manually to separate the clean one from the unclean.After dehulling and washing process, the samples were collected. The mass of undehulled beans, mass of boiled beans, whole beans, broken beans in the final product, mass of the coat, weight of clean beans and mass of dehulled beans were determined respectively. The performance evaluation of the machine was determined based on dehulling efficiency, cleaning efficiency and percentage loss, which are calculated respectively at different boiling/soaking time and replicated three (3) times. Plates 1-10 shows different operations on the performance evaluation of the dehulling machines.

Plate 1: Circular-sieved Dehuller

Plate 2: Rectangular-sieved Dehuller

Plate 3: Locust Bean during cooking

Plate 4: Beans being weighed

Plate 5: Samples of the Beans

Plate 6: Navy Beans during soaking

Plate 7: Kidney Beans during soaking

Plate 8: Soybeans during soaking

Plate 9: Dehulling Machine

Plate 10: Dehulling Process

(d) Performance Evaluation of the Machine

The performance evaluation was carried out using four varieties of beans (locust beans, soybeans, kidney beans and navy beans) and was aimed at determining the dehulling efficiency, cleaning efficiency and percentage loss based on boiling time and soaking time. The machine operational parameters are determined as follows:

(i) Dehulling Efficiency: It is the ratio of the mass of dehulled beans to the total mass of boiled beans expressed in percentage and is expressed as:

$$D_e = \frac{M_{db}}{T_{bb}} \times 100\%$$

Where: $D_e = Dehulling\ Efficiency$;
$M_{db} = Mass\ of\ Dehulled\ Beans$;
$T_{bb} = Total\ Mass\ of\ Boiled\ Beans$.

(ii) Cleaning Efficiency: It is the ratio of the weight of clean beans to the total weight of coat and dehulled beans expressed in percentage and is given as:

$$C_e = \frac{W_c}{W_{ct} + W_{db}}$$

Where: $C_e = Cleaning\ Efficiency$;
$W_{ct} = Weight\ of\ Coat$;
$W_{db} = Weight\ of\ Dehulled\ Beans$.

(iii) Percentage Loss: It is the ratio of the weight of clean beans to the total weight of boiled beans expressed in percentage and is expressed as:

$$P_l = \frac{M_{udb}}{T_{bb}}$$

Where: $P_l = Percentage\ Loss$;
$M_{udb} = Mass\ of\ Undehulled\ Beans$;
$T_{bb} = Total\ Mass\ of\ Boiled\ Beans$

III. Results and Discussion

(a) Performance Evaluation Results of the Dehullers on Locust Beans

It could be deduced from Table 1 that the dehulling efficiency increased with the boiling time and dehulling time at minimum and maximum values of 80.40% and 85.87% on circular sieve while at minimum and maximum values of 88.50% and 88.40% on rectangular sieve respectively. It was observed that at a higher boiling time, the coats were softened therefore making the dehulling easier with less breakage of the seeds since its elasticity increases with boiling time. The results obtained was in accordance with [7] and [8]. It was also observed on circular sieve that the cleaning efficiency decrease from 73.04% to 71.47% while on rectangular sieve, the cleaning efficiency increases from 58.77 to 66.16% at the boiling time of 7, 8 and 9 hours. It can be inferred that the dehulling efficiency increases the quality of the dehulled beans while cleaning efficiency increases the quality of undehulledbeans, thereby making the separation efficiency to be on a positive increase. The resultsare highly correlated and linear in relation with the study carried out by [1]. It can be seen that the percentage loss of damaged beans decreases with the boiling time and dehulling time. The minimum and maximum percentage loss of 19.53% and 14.11% were obtained on circular sieve while the minimum and maximum percentage loss of 13.07% and 11.50% were obtained on rectangular sieve at 7 and 9 hours of boiling time respectively. This occurred as a result of increase in dehulling and cleaning efficiencies, the weight of undehulled beans reduces which was in accordance with the study carried out by [1]. Figure 1 shows the relationship that existed between boiling time, dehulling time, dehulling efficiency, cleaning efficiency and percentage loss during performance evaluation tests for locust beans.

Table1: Results of Performance Evaluation Tests on Locust Beans

Mass of Beans (kg)	Boiling Time (hrs)	Dehulling Time (secs) (Circular Sieve)	Dehulling Time (secs) (Rectangular Sieve)	Dehulling Efficiency (%)		Cleaning Efficiency (%)		Percentage Loss (%)	
				Circular Sieve	Rectangular Sieve	Circular Sieve	Rectangular Sieve	Circular Sieve	Rectangular Sieve
3	7	68.67	67.33	80.40	88.50	73.04	58.77	19.53	13.07
3	8	71.67	71.00	82.07	87.73	71.16	59.91	17.83	11.63
3	9	61	74.67	85.87	88.40	71.47	66.16	14.10	11.50
Avg.	8	67.11	71.00	82.78	88.21	71.89	61.61	17.15	12.07

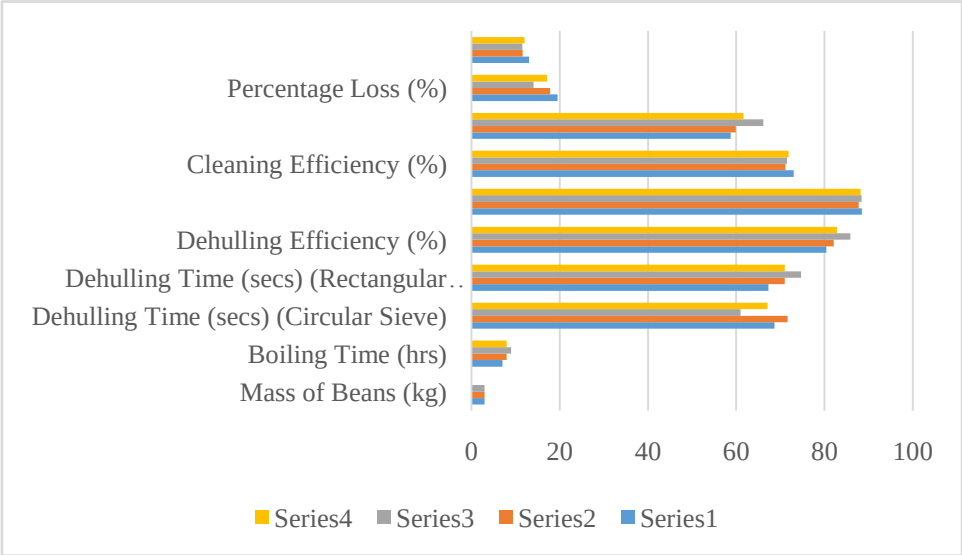

Figure 1: Relationship between Boiling Time, Dehulling Time, Dehulling Efficiency, Cleaning Efficiency and Percentage Loss for Performance Evaluation Tests on Locust Beans

(b) Performance Evaluation Results of the Dehullers on Soybeans

It can be observed from Table 2 that the dehulling efficiency increases the soaking time and dehulling time at minimum and maximum values of 78.67% and 85.87% on circular sieve and also at minimum and maximum

values of 68.00% and 76.33% on rectangular sieve. This implies that the dehulling efficiency increased with soaking time and dehulling time. It can be observed from the experiment that at soaking, when the coat is very soft, it increases the water holding capacity of the coat which was confirmed in the study by [9]. It could also be observed that the minimum and maximum cleaning efficiencies of 57.52% and 54.52% on circular sieve and 58.12% and 59.52% on rectangular sieve were obtained respectively. It could also be inferred that the rectangular sieve increases the cleaning efficiency with increase in soaking time. According to [1], the dehulling efficiency increases the quality of clean beans. It can be observed that the percentage lossof 21.33% and 14.1% on circular sieve, and 32.00% and 23.63% on rectangular sieve were obtained respectively, which decreased with the soaking time and the boiling time. [1]stated that as a result of increase in dehulling and cleaning efficiencies, the weight of undehulled beans reduces. The relationship between boiling time, dehulling time, dehulling efficiency, cleaning efficiency and percentage loss during performance evaluation for soybeans is shown in Figure 2.

Table 2: Results of Performance Evaluation Tests on Soybeans

Mass of Beans (kg)	Boiling Time (hrs)	Dehulling Time (secs) (Circular Sieve)	Dehulling Time (secs) (Rectangular Sieve)	Dehulling Efficiency (%)		Cleaning Efficiency (%)		Percentage Loss (%)	
				Circular Sieve	Rectangular Sieve	Circular Sieve	Rectangular Sieve	Circular Sieve	Rectangular Sieve
3	8	76.33	56.67	78.67	68.00	57.52	58.12	21.33	32.00
3	9	63.33	64.67	80.07	71.63	53.34	64.03	19.87	28.30
3	10	73.67	61.67	85.87	76.33	54.92	59.52	14.1	23.63
Avg.	9	71.11	61.00	81.54	71.99	55.26	60.56	18.43	27.98

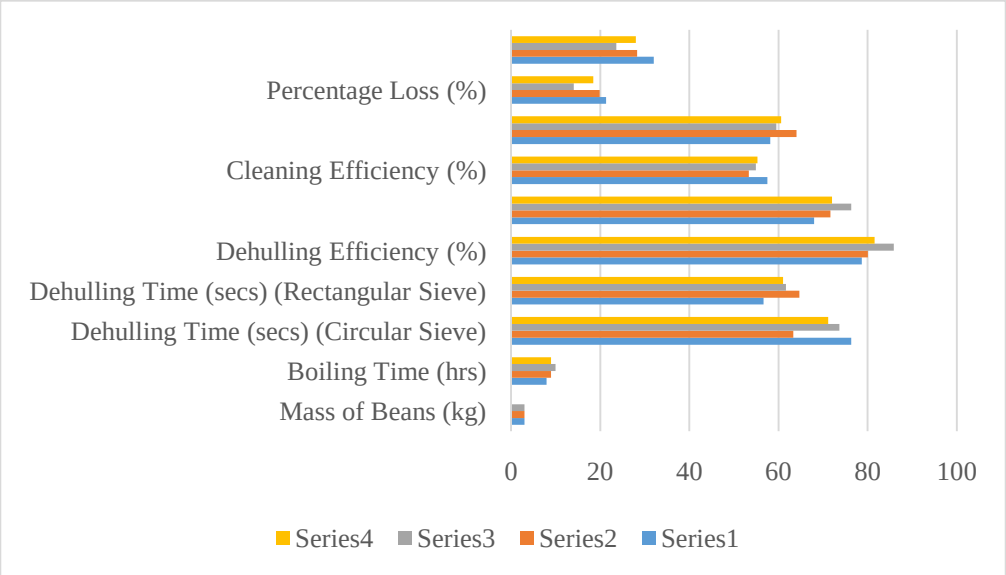

Figure 2: Relationship between Boiling Time, Dehulling Time, Dehulling Efficiency, Cleaning Efficiency and Percentage Loss for Performance Evaluation Tests on Soybeans

(c) Performance Evaluation Results of the Dehullers on Kidney Beans

It can be seen from Table 3 thatthe dehulling efficiency increased with the soaking time and dehulling time with the minimum and maximum valuesof 72.07% and 83.39% on circular sieve and 63.63% and 75.50% on rectangular sieve respectively. [9]confirmed that soaking makes the coat to be very soft and thereby increases the water holding capacity of the coat. It could also be observed that the cleaning efficiencydecreases with increase in soaking time on circular sieve with the minimum and maximum values of 58.78% and 55.92% and 63.78% and 60.94% on rectangular sieve. The low cleaning efficiency obtained initially was probably due to hard seed coat which were difficult to remove thereby leaving undehulled beans and a larger part of few cotyledons obtained were broken [1]. It can be deduced also that the percentage loss decreases from 27.87% to 16.63% on circular sieve and 36.30% to 24.40% on rectangular sieve. This occur as weight ofundehulled beans reduces [1].Figure 3 shows the relationship that existed between boiling time, dehulling time, dehulling efficiency, cleaning efficiency and percentage loss during performance evaluation tests for kidney beans.

Table 3: Results of Performance Evaluation Tests on Kidney Beans

Mass of Beans (kg)	Boiling Time (hrs)	Dehulling Time (secs) (Circular Sieve)	Dehulling Time (secs) (Rectangular Sieve)	Dehulling Efficiency (%)		Cleaning Efficiency (%)		Percentage Loss (%)	
				Circular Sieve	Rectangular Sieve	Circular Sieve	Rectangular Sieve	Circular Sieve	Rectangular Sieve
3	7	60.67	57.33	72.07	63.63	58.78	63.78	27.87	36.30
3	8	63.67	62.67	76.31	69.20	61.50	63.42	23.65	30.77
3	9	71.33	68.67	83.30	75.50	55.92	60.94	16.63	24.40
Avg.	8	65.22	62.89	77.23	69.44	58.73	62.71	22.72	30.49

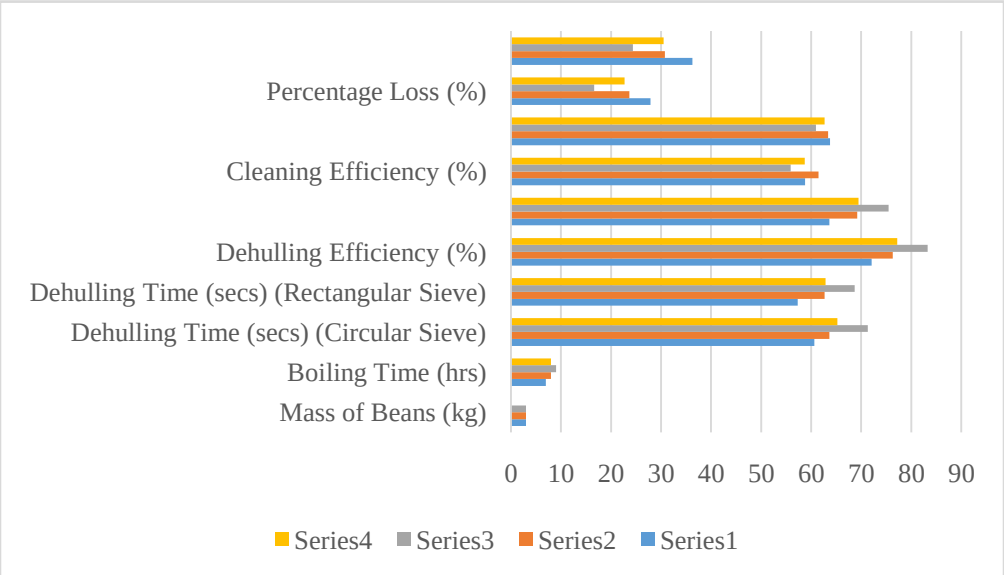

Figure 3: Relationship between Boiling Time, Dehulling Time, Dehulling Efficiency, Cleaning Efficiency and Percentage Loss for Performance Evaluation Tests on Kidney Beans

(d) Performance Evaluation Results of the Dehullers on Navy Beans

It can be observed from Table 4 that the dehulling efficiency with the use of circular sieve increased with soaking time and dehulling time at minimum and maximum values of 72.87% and 82.43%, and 65.40% and 74.30% on rectangular sieve respectively. It was seen that the soaking makes the coat very soft and also increases the water holding capacity of the coat [9]. It can be seen that the cleaning efficiency with the minimum and maximum values of 56.54% and 59.25% on a circular sieve and 58.73% and 60.25% on rectangular sieve increases with soaking time and dehulling time respectively. [1] confirmed that as the dehulling efficiency increases, the quality of clean bean also increases. It can be seen that the percentage loss decreases from 27.07% to 17.30% on circular sieve and 34.53% to 24.07% on rectangular sieve. This occur as weight ofundehulled beans reduces [1]. The relationship between boiling time, dehulling time, dehulling efficiency, cleaning efficiency and percentage loss during performance evaluation for navy beans is shown in Figure 4.

Table 4: Results of Performance Evaluation Tests on Navy Beans

Mass of Beans (kg)	Boiling Time (hrs)	Dehulling Time (secs) (Circular Sieve)	Dehulling Time (secs) (Rectangular Sieve)	Dehulling Efficiency (%)		Cleaning Efficiency (%)		Percentage Loss (%)	
				Circular Sieve	Rectangular Sieve	Circular Sieve	Rectangular Sieve	Circular Sieve	Rectangular Sieve
3	7	61.67	67.67	72.87	65.40	56.54	58.73	27.07	34.53
3	8	72.00	71.33	78.77	71.40	59.55	62.82	21.20	28.73
3	9	71.33	68.33	82.43	74.30	59.25	60.25	17.30	24.07
Avg.	8	68.33	69.11	78.02	70.37	58.45	60.60	21.86	29.11

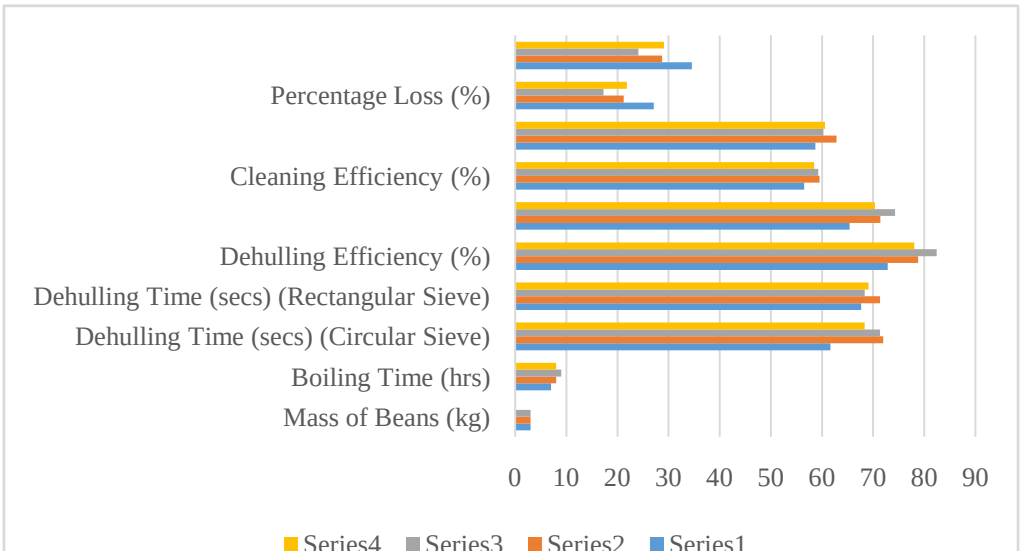

Figure 4: Relationship between Boiling Time, Dehulling Time, Dehulling Efficiency, Cleaning Efficiency and Percentage Loss for Performance Evaluation Tests on Navy Beans

Plates 11-14 shows the beans after being dehulled and other dehulling processes using the dehulling machine.

Plate 11: Dehulled Soybeans

Plate 12: Loss

Plate 13: Kidney Bean Shaft

Plate 14: Dried Dehulled Beans

IV. Conclusion

A locust bean dehulling machine was modified and evaluated while the following conclusions were drawn:

1. The average dehulling efficiencies of the circular-sieved machine for locust beans, soybeans, kidney beans and navy beans are 82.78%, 81.54%, 77.23% and 78.02% respectively at average dehulling time of 67.11 secs, 71.11 secs, 65.22 secs and 68.33 secs respectively while 88.21%, 71.99%, 69.44% and 70.37% respectively were obtained for the rectangular-sieved machine at average dehulling time of 71.00 secs, 61.00 secs, 62.89 secs and 69.11 secs respectively.
2. The average cleaning efficiencies of the circular-sieved machine for locust beans, soybeans, kidney beans and navy beans are 71.89%, 55.26%, 58.73% and 58.45% respectively at average dehulling time of 67.11 secs, 71.11 secs, 65.22 secs and 68.33 secs respectively while 61.61%, 60.56%, 62.71% and 60.60% respectively were obtained for the rectangular-sieved machine at average dehulling time of 71.00 secs, 61.00 secs, 62.89 secs and 69.11 secs respectively.
3. The percentage loss of the circular-sieved machine for locust beans, soybeans, kidney beans and navy beans are 17.15%, 18.43%, 22.72% and 21.86% respectively at dehulling time of 67.11 secs, 71.11 secs, 65.22 secs and 68.33 secs respectively while 12.07%, 27.98%, 30.49% and 29.11% respectively were obtained for the rectangular-sieved machine at average dehulling time of 71.00 secs, 61.00 secs, 62.89 secs and 69.11 secs respectively.

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